Remarks/Arguments

Request for Reconsideration

Applicant has carefully considered the matters raised by the Examiner in the outstanding Office Action but remains of the opinion that patentable subject matter is present. Applicant respectfully requests reconsideration of the Examiner's position based on the following remarks.

Status of the Claims

Claims 1 – 6 were pending, and are still pending. Applicant notes that the previous amendment presented dependent Claims 5 – 7, which the Examiner properly considered as Claims 4 – 6. These claims have been properly numbered herein as Claims 4 - 6. Claims 1 – 6 are being amended. Claims 7 – 9 are being added. Claims 1 – 9 are pending and under consideration. Amended Claims 1 and 2 respectively correspond to Claims 1 and 2 before the Amendment of November 4, 2008. New Claim 7 corresponds to Claim 1, before the present Amendment, and new Claim 8 corresponds to Claim 2 before the present Amendment, and new Claim 9 corresponds to the present Claim 3 before the Amendment. Accordingly, no new matter has been added.

Section 103 Rejection

The Examiner rejected Claims 1 – 6 under 35 U.S.C. 103(a) as being unpatentable over Nowlin et al. U.S. Patent No. 6,879,880 (hereinafter "Nowlin") in view of Murakami et al. "*Force Sensorless Impedance Control by Disturbance Observer*", IEEE 1993. In view of the arguments and amendments herein, applicant respectfully traverses the rejection and submits that Claims 1 – 6, as well as new dependent Claims 7 – 9, are allowable over the references.

In the Office Action, the Examiner stated that Nowlin disclosed elements (i), (ii), and (iv) of Claim 1, but not element (iii), which recites in part:

> "reaction force detected in means for estimating a reaction force
> which the object receives, where the reaction force is detected

> indirectly based on a position signal outputted from the position detection means and a driving signal applied to the driving means."

The Examiner stated that Murakami disclosed the part of (iii) quoted above. The Examiner did not state that Murakami disclosed the last part of (iii), which recites:

> "and where frictional force and inertia variation on the object are subtracted as known values."

The presently-claimed invention introduces acceleration control that pays attention to acceleration which is a common dimension to force and position for attaining force control and position control simultaneously, as described in detail below. The acceleration control is recited in independent Claim 1 (iv), Claim 2 (iv), (v), (vi), and Claim 3 (vii), (viii), (ix), (x). The references of Nowlin and Murakami do not teach or suggest these components concerning the foregoing acceleration control.

Applicant will first describe a difference between the proposed combination of the cited reference of Nowlin (USP 6,879,880) and the cited reference of Murakami, and the presently-claimed invention. The cited references are different from the presently claimed invention in the operation principles. Also, these references are different from, and do not teach, the presently-claimed invention.

Both of the cited references recognize force held by a manipulator in compliance control. A difference between the references and the presently claimed invention is similar to a difference between (1) force held by radio pliers with spring (references), and (2) force held by radio pliers without spring (presently claimed invention). In case of the radio pliers with spring, it is easy to operate. The references are the same as radio pliers with spring, which is easy to use but is limited by some conditions in action. In other words, radio pliers with hard spring make it difficult to recognize actual hardness of a subject to be held. In the references, measurement of the hardness is

possible under a condition in which the hardness of the subject is larger and the spring is softer than the hardness.

Fundamentally, each measurement of the references does not mean direct measurement. In the Nowlin reference, the spring is illustrated. Also the Murakami reference in Fig.4 illustrates the spring and impedances Kf and Df. Further, there is a limitation of the condition where hardness can be measured. For example, as shown in an expression (9) in the Murakami reference if the numerical value of (MvnS2 + DfS + Kf) at x = -(MvnS2 + DfS + Kf)-1 Fext is zero, then x becomes indefinite because there is (-1) power. In contrast, in the presently-claimed invention there is no said limitation, and hence any proposed combination of the references are not the same as, and do not teach, the presently-claimed invention. In Fig.3 of Murakami, reaction force is estimated on subtracting three terms of interference force (T_{inti}), gravity effect (T_{gi}), Coulomb friction and viscous friction ($F_i + D_i q_i$) in calculation process by the disturbance observer. In contrast, as described, in Fig.6 of the present application, torque produced with inertia variations is subtracted from disturbance together with frictional force, which subtraction is not conducted or taught in the Murakami reference. Additionally, in Murakami's embodiment, as understood from a fact that (q_i) is inputted from right upper side in Fig.3, reaction force estimation is done by using velocity information (namely differentiation of position information), while in the presently-claimed invention reaction force estimation is done by using x (namely position information) as illustrated in Fig.6.

Applicant also notes that Nowlin and Murakami relate to different approaches, and one skilled in the art would not find it obvious to combine their teachings. Murakami describes research concerning "force control" such as impedance control and compliance control as understood from words shown in the reference. In contrast, Nowlin discloses a technique based on "position control"

(although, control simulating spring is actually applied in part as described before, it could be regarded basically as position control). Although the presently-claimed invention has been rejected on combination of both references as being obvious, the combination is physically impossible as described below. First, the following control stiffness is introduced as an index to indicate the property of the control ($\kappa = \partial f / \partial x$). This simply represents a ratio of variation of force and variation of position. Ideal force control has no error on force information, which indicates zero of the variation of force. Then $\partial f=0$ should hold, resulting in control stiffness $\kappa=0$. Against this, ideal position control has no error on position information, which indicates zero of the variation of position, so that $\partial x=0$ should hold, resulting in control stiffness $\kappa=\infty$. In other words, both controls have exactly opposite control target, so that no simple combination of the force control and the position control is physically allowed. In sharp contrast, the presently claimed invention introduces acceleration control which adopts acceleration of a common dimension to force and position, in order to simultaneously realize force control and position control. In the dimension of acceleration, force control is realized in a "common mode" while position control is realized in a "differential mode", as shown in the following:

$$f_m + f_s = 0 \rightarrow \ddot{x}_m + \ddot{x}_s = 0$$

$$x_m - x_s = 0 \rightarrow \ddot{x}_m - \ddot{x}_s \rightarrow 0$$

The upper equation provides a control rule for realizing the law of action and reaction between a master and a slave, indicating the control for making zero of the summation of accelerations of the master and the slave. In contrast, the lower equation provides a control rule for realizing position tracking between the master and the slave, indicating the control for making zero of the difference between the accelerations of the master and the slave.

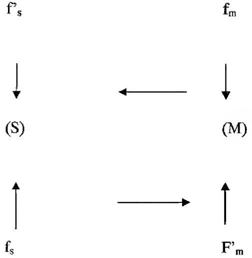
Paying our attention to the accelerations of the master and the slave, the force control is to make the sum zero (common mode) while the position control is to make the difference zero (differential mode), and these modes can be described using the following Hadamard matrix:

$$\begin{bmatrix} \ddot{x}_c \\ \ddot{x}_d \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} \ddot{x}_m \\ \ddot{x}_s \end{bmatrix}$$

where $\ddot{x}_c$ is the acceleration of the common mode and $\ddot{x}_d$ is the acceleration of the differential mode. The Hadamard matrix is an orthogonal matrix, so that both modes are independent without any interference. In such a manner, the force control and the position control are implemented in independent modes: the common mode and the differential mode in the acceleration dimension, so that both controls can simultaneously be realized by introducing the acceleration control.

The presently claimed invention introduces the acceleration control and notices that both controls can be independently and simultaneously attained in the acceleration dimension that is a common dimension to both force and position. Thus, simultaneous and independent attainment of the controls is made possible. In case of a proposed combination of Murakami and Nowlin, however, simultaneous use of the force control and the position control is not physically possible, since the acceleration control is not introduced. Thus, even if the references were combined the presently-claimed invention is not obvious over the Nowlin and Murakami references.

Although in the above discussion, the difference was described using the Hadamard matrix, the present specification does not discuss the Hadamard matrix itself. However, the specification contains the same contents are contained as described below. Action force on the Master side is assumed f_m, and reaction force f'_m. Likewise, action force on the Slave side is assumed f'_s and its reaction force f_s. Arrows (↓↑) in the following figure indicate the plus direction.



Control: $f_m + f_s = 0$ is implemented in the presently claimed invention.

Reaction on the slave side

Description of Drawing

When force f_m is applied to the Master side, it is transmitted to the Slave side, in the presently-claimed invention, to permit force f'_s to appear. Reaction against the action force appears on the Slave side, the magnitude thereof is assumed f_s. The f_s is transmitted to the Master side, in the presently claimed invention, to permit force f'_m to appear on the Master side as the reaction force. Then, the law of action and reaction holds on both the master side and the slave side.

$f_m + f'_m = 0$ Law of action and reaction on Master side

$f'_s + f_s = 0$ Law of action and reaction on Slave side

The force is transmitted as ($f_m \rightarrow f'_s$) to permit reaction force f_s to appear on the Slave side, which is transmitted to the Master side to permit f'_m to appear. On the Master side action force f_m brings about reaction force f'_m, which is the same as f_s. The presently-claimed invention therefore realizes

$f_m + f_s = 0$ artificially. This means an operator on the master side feels the same reaction force as that given by directly pushing the Slave side. The law of action and reaction is artificially realized as follows:

$f_m + f_s = 0$ (law of action and reaction)

↓↑

$\ddot{x}_m + \ddot{x}_s = 0$ (acceleration control)

Further, tracking property of position is realized as follows:

$x_m - x_s = 0$ (tracking property)

↓↑

$\ddot{x}_m - \ddot{x}_s \rightarrow 0$ (acceleration control)

This is supported in Fig. 1, Fig.5, Fig. 12 and Fig.13 of the present application:

[Fig.1]

x_m and x_s applied to the position control 5

F_m and F_s applied to the operation force control part 6

[Fig.5]

X_m and X_s applied to the part 5a of the position control 5

F_m and F_s applied to the part 6a of the operation force control 6

[Fig.12]

x_{ref} and x_s applied to the position control part 15

f_{ref} and F_s applied to the operation force control part 16

[Fig.13]

x_{ref} and X_s applied to the part 15a of the position control 15

f_{ref} and F_s applied to the part 16a of the operation force control 16

Also, Murakami does not disclose having "a frictional force and inertia variation being subtracted as known values", as recited in new Claims 7, 8, and 9. Therefore, even if Nowlin and Murakami were somehow combined, the combination would not provide the invention as recited in Claims 7, 8, and 9.

Therefore, in view of the arguments herein, applicant respectfully traverses the rejection and submits that the pending claims are allowable over the references.

Fees

A one-month extension fee of $65 for a small entity is being paid. No other fees are believed to be due. However, if any other fee is determined to be due, authorization is hereby given to charge the fee to deposit account #02-2275. Pursuant to 37 C.F.R. 1.136(a)(3), please treat this and any concurrent or future reply in this application that requires a petition for an extension of time for its timely submission as incorporating a petition for extension of time for the appropriate length of time. The fee associated therewith is to be charged to Deposit Account No. 02-2275.

Conclusion

In view of the amendments and arguments presented, it is respectfully submitted that each and every one of the matters raised by the Examiner has been addressed by the present amendment and that the present application is now in condition for allowance.

An early and favorable action on the merits is earnestly solicited.

Respectfully submitted

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I hereby certify that this document is being electronically transmitted to the Commissioner for Patents via EFS-Web on June 22, 2009.

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